REPLACING AN URBAN FOUNDATION

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An extension of Baltimore's Metro subway will pass through the Inner Harbor area, where dewatering could hasten deterioration of timber piles that support several old buildings. To stabilize one of these, the specialty contractor replaced the original foundation with pin piles.

Adding new infrastructure to an old city can disrupt more than the right-of-way. In Baltimore, driving a tunnel for the northeast extension of the Baltimore Metro subway involves dewatering parts of the Inner Harbor area, where new construction mingles with old buildings.

The area has been undergoing redevelopment for nearly two decades, with new commercial, governmental and sports facilities straining the area's transportation and utility services. All this prompted the Mass Transit Administration (MTA) to resume construction of the Metro subway, extending it northeast from the existing Charles Center (downtown) station to Johns Hopkins University.

This third Metro segment, known as Section C, is about ½ mi long. Its two stations, one at the Shot Tower and one at Johns Hopkins Hospital, are also underground. Total cost is expected to be $321 million, with completion scheduled for late 1994.

Near the Inner Harbor, the tunnel passes close to the six-story Bernstein Building, which was built in 1910 after the Great Baltimore Fire of 1906 leveled the area. It is a reinforced concrete structure, 75 by 85 ft, with load-bearing masonry and stone walls. No as-built drawings can be located, but when utility construction for the subway extension began, excavation in the basement revealed its timber pile foundation.

The butt diameters of the untreated piles were 10–12 in. Interior columns bore on groups of nine to 12 piles and exterior columns on six to eight piles. Soft rot and fungus had penetrated the interior piles, and worse problems were foreseen during the projected dewatering. The local ground elevation varies from El 7 to 10 ft, the final basement floor of the Bernstein Building is El 1, and the water table is at El 0.

FUTURE TUNNEL CONSTRUCTION ENDANGERED THE FOUNDATION OF A CONCRETE BUILDING FROM 1910.

The upper 9–12 ft of soil is loose random fill, including rubble, bricks, wood and ash left from the fire. An organic layer of soil separates this fill from dense to very dense Cretaceous sands and gravel, where the wood piles developed their capacity by end bearing and friction. The computed loads provided by the owner were 250 tons on the interior columns and 162 tons on the exterior columns, but the design engineers decided that they were already loaded at or beyond allowable capacity.

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The engineering firm, DKP, is a joint venture of Daniel, Mann, Johnson & Mendenhall; Kaiser Engineers, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc. Its engineers predicted that dewatering for adjacent tunnel construction could draw down the ground-water level to El -25 ft. This would consolidate the organic layer and dry out the pile butts, accelerating decay and cracking the basement slab. Differential settlements would distort the building frame.

The DKP engineers devised a conventional underpinning solution whereby 10 ft of soil would be removed from around the piles, which would be encased in concrete. The organic soil supporting the basement floor would then be replaced with granular material. General contractor Kiewit/Shea, another joint venture, solicited competitive bids; Nicholson Construction, Inc. (NCI) was the successful bidder.

After submitting the bid, NCI engineers reconsidered their strategy. Given the soft layer of soils, the deterioration of the existing timber piles and the time constraints of the project, they reasoned that a pin pile solution offered several benefits. It would limit the the excavation depths, the amount of undermining at at any one time and the total undermining time, while avoiding contact with the water table. The project schedule and overall quality could be better controlled.

Pin piles are still relatively new in U.S. construction (CE December 1988, page 57). They are typically 6–10 in. diameter and can be as long as 200 ft. Varying the nature of the composite grout and steel section allows them to be designed to resist compressive, tensile or bending stresses, or combinations of all three. Installed with special drilling and pressure grouting techniques, they have very good load-deflection characteristics, as load is primarily transferred to the bearing stratum by skin friction.

Initial redesign of the foundation project indicated that 120 pin piles with an individual design capacity of 140 kips would support 100 linear ft of load-bearing wall and 20 individual columns. This scheme was accepted by DKP, the MTA and the building owner. An intensive test program was set up, but final design calculations and shop drawings were prepared, and excavation begun, before reviews of the test results were completed.

CONSTRUCTION

Underpinning the Bernstein Building with pin piles was done in four distinct phases: (1) Mass excavation and exploration; (2) pile installation; (3) hand excavation under existing timber pile caps and (4) placing rebar and concrete for new caps. Each of these phases required new design concepts, redesign of approved concepts and a review process for both, without delaying the schedule.

EXCAVATION STARTED WITH MACHINES, BUT, BEFORE WOOD PILES WERE REPLACED, THE AREA UNDER THE OLD CAP HAD TO BE DUG BY HAND TO PLACE REBAR FOR THE NEW CAP AND BEAM.

Mass excavation and exploratory work were done with a track mini-excavator feeding a chain of conveyors. The crew first broke through the brick foundation wall to the basement and broke up the existing slab on grade. When the working headroom had been increased from 5 to 8 ft, they placed a 6 in. reinforced concrete mud mat to provide a controlled working surface.

Installing the pin piles required three steps. First, for drilling, the mud mat helped the crew meet tolerances in locating and aligning the mast of the diesel hydraulic drilling rig. With water as the flushing medium, they drilled 3 ft sections of 7 in. diameter casing to El -30. The second step was to clean the casing by flushing and to inject via tremie tube a neat grout of one bag of Type I cement to 5 gal. water. Then the crew placed a 25 ft length of No. 11 Grade 60 reinforcing bar at the bottom of the cased hole, splicing it several times with mechanical couplers because of the limited headroom.

The final installation phase required that the drill rig head be reattached to the casing for pumping more grout against the liquid head of the first placement. Pumping while rotating the casing continued until grout pressure built to 100 psi, at which time the casing was slowly extracted, being broken off 3 ft at a time. Repeating this procedure seven times left a 21 ft pressure bulb of reinforced grout.

During the four or five days required for the grout to reach its target strength of 4,000 psi, the new caps were completed so that the building load could be transferred to the pin pile. First, the soil beneath the existing timber pile cap or load-bearing wall had to be removed by hand. The space available to the workman often determined the depth of the new cap. As he scraped away loose surface material, the engineers had to make final design modifications and submit them for review and approval.

This step proved critical because at this point the structure above was supported only by the exposed timber piling, which in turn obstructed rebar and concrete placement for the cap that completed the load transfer. Because the timber pile sizes and planned location varied, the rebar had to be shifted and bent horizontally and vertically. Each placement was a custom job and inspec-

tion was critical to assure that the formwork could be closed in time to keep the concrete schedule.

Pumping all concrete solved the problems of limited work areas and restricted access, but several other special conditions required instant engineering decisions on the spot. Baltimore's great fire had leveled the area early in this century, and subsequent rebuilding had covered many objects that are now uncovered as archeological artifacts. The Nicholson labor force, working with the DKP inspectors, recovered significant objects from the peat layers while limiting delays to the schedule.

One instant engineering decision involved an overloaded column where, instead of the expected nine to 12 timber piles, we found only four. The owners had moved an exterior wall in one of the many previous renovation projects, placing a load of some 480 kips on a 12 in. square interior column. We shored the load temporarily to nearby permanent pin piles with a steel needle beam, later incorporating the beam into the final support configuration.

Many schematic changes evolved during design reviews. One occurred when the DKP engineering staff discovered that its initial

Replacing old wood piles with pin piles would limit the undermining required at any one time to stabilize the masonry building.

design placed pile tips for one line of exterior columns directly in the path of the pending subway tunnel. The final redesign provided a strap slab support cantilevering over a row of pin piles along the interior face of these columns. The hold-down for the slab was provided by structural key and shear dowels in the interior pin pile cap.

Eccentrically located timber pile clusters also caused problems. During mass excavation, we discovered insufficient timber pile support under an interior column because a timber and stone mat occupied about one-third of the cap area. Redesign took advantage of the solution developed for the exterior columns.

We positioned the pin piles between the column and exterior wall, breaking the cantilevered support slab into two segments, each designed as a temporarily double cantilevered slab. This allowed the remaining two-thirds of the existing cap to be excavated and concreted without disturbing the timber and stone construction. We retained the usual configuration for the permanent reinforcement of the new pile cap, adding mechanical splices to accommodate the cold concrete joint when we changed the cap from monolithic to segmental construction.

On another column, we discovered a similar stone and timber mat, but here three timber piles had been chopped off, leaving only 2 ft stubs hanging down on one-third of the area. We were able, however, to repeat the segmental cap solution.

TESTING

The load test program was developed, reviewed, modified and approved while the final design calculations and shop drawings were being prepared, a lengthy process. We used a version of the standard ASTM quick compression test (D-1143) that incorporated cycles of the load steps back to the alignment increases. This identified the elastic and permanent components of deformations.

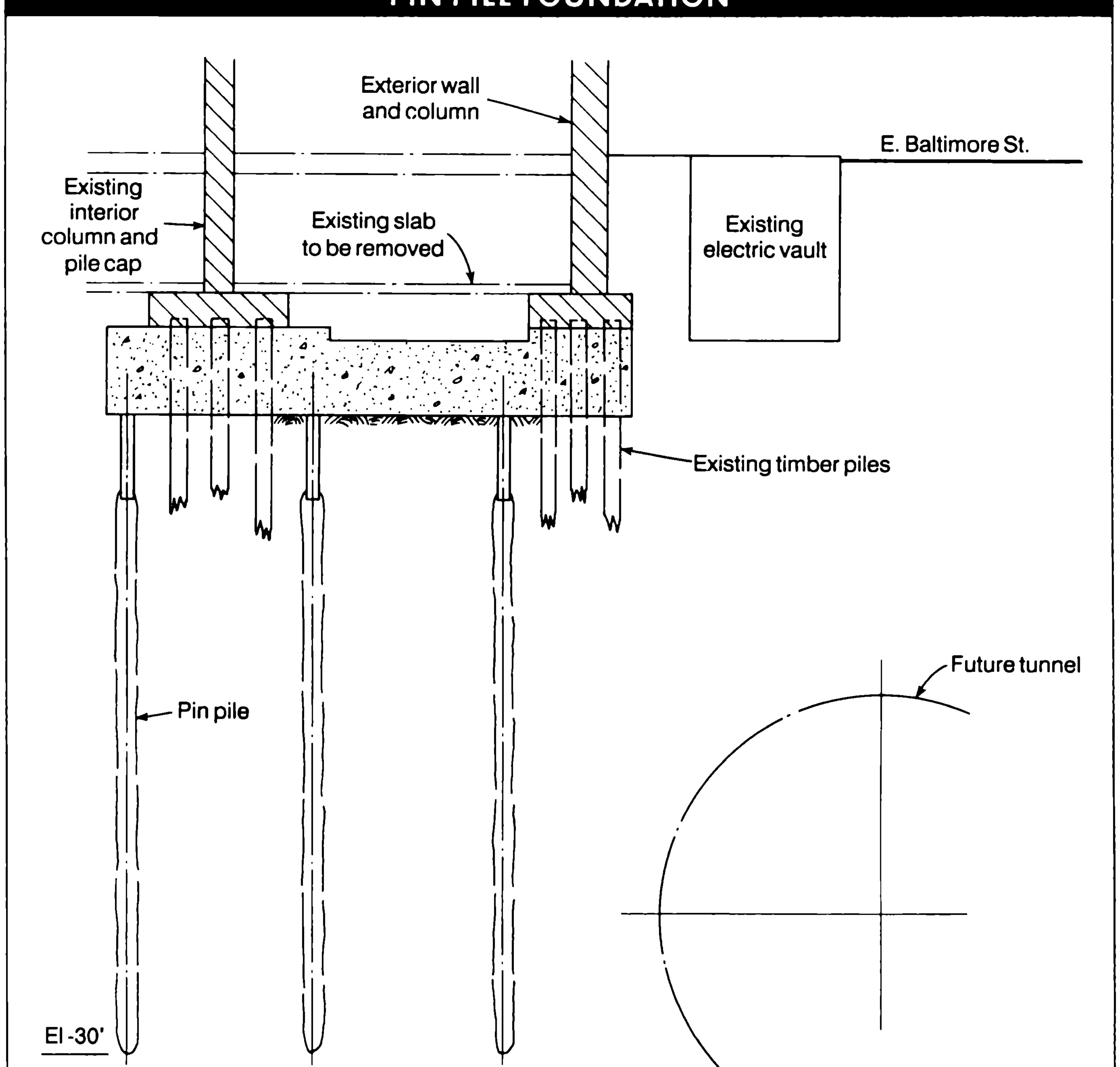
The tests showed that at the design load of 140 kips the pin pile head moved about $\frac{1}{16}$ in., and at the subsequent alignment load of 7 kips, the permanent settlement was less than $\frac{1}{64}$ in. At the test load of 280 kips, head movement was about $\frac{3}{16}$ in. Upon unloading, the permanent displacement was significantly less than $\frac{1}{64}$ in.

We also elected to continue testing the pile in compression to a loading of 500 kips, the safe working capacity of the hold-down system. It held, and for safety reasons we stopped further loading. On complete unloading, net movement was slightly more than $\frac{1}{32}$ in. These test results far exceeded project requirements.

Building survey elevation readings verified the service performance of the production piles. We had observed and recorded many signs of distress without knowing what settlement the structure had experienced over the years, yet during the project, recorded settlements were generally less than $\frac{1}{2}$ in. Plotting time/settlement data for each column showed a straight line from start of mass excavation until the cap was concreted, when settlement stopped.

The Mass Transit Authority (MTA) funded this work as part of its ongoing subway construction project. DKP provided design, inspection and construction management. The specialty contractor was Nicholson Construction, Inc., Frederick, Md.

PIN PILE FOUNDATION



OLD TIMBER PILES SUPPORTING A BALTIMORE BUILDING WERE REPLACED WITH PIN PILES TO PREVENT BUILDING DAMAGE DURING CONSTRUCTION OF THE ADJACENT SUBWAY TUNNEL.